# SYSTEM AND METHOD FOR HEAT TREATING A HOMOGENIZED FLUID PRODUCT

## Background

**[0001]** The present invention relates to a system and method for heat treating a homogenized fluid product. The present invention has applicability in the food, beverage, pharmaceutical, biotechnology, semiconductor, paint, ink, toner, fuel, magnetic media, and cosmetic industries.

**[0002]** Many different types of fluid products are heat treated, either through heating and/or cooling, during the production process. For example, during a pasteurization process, a fluid product such as a fruit juice is heated for a sufficient amount of time and at a sufficient temperature to kill all or substantially all of the microorganisms initially present in the liquid.

**[0003]** In another example, during a homogenization process, two or more fluid product ingredients can be subjected to shear forces, impact forces, and/or cavitation to form a homogenized fluid product. The shear forces, impact forces, and/or cavitation can cause a significant increase in temperature of the resultant fluid product. If one or more of the fluid product ingredients is a temperature sensitive material such as biological, organic, pharmaceutical, cellular, microbial, plant extracts, animal extracts, and certain food materials, the homogenized fluid product should be quickly cooled to prevent damage to the temperature sensitive material. Otherwise, the temperature sensitive material may be destroyed and wasted.

**[0004]** There are several methods known in the art to cool a homogenized fluid product. One such method is to introduce a cooling liquid such as water or a cooling agent to the fluid product. Such a method can reduce the temperature of the fluid product post-homogenization; however, the cooling liquid must be separated from the fluid product at a later stage in the process.

**[0005]** Another method to cool a homogenized fluid product is to introduce a compressed gas such as air or nitrogen to the homogenized fluid product. Once again, such a method can reduce the temperature of the fluid product post-homogenization; however, the compressed gas must be separated from the fluid product at a later stage in the process. Also, the compressed gas can react with the fluid product ingredients.

**[0006]** Yet another method to cool a homogenized fluid product is to introduce a cooled liquid that is the same liquid as one of the fluid product ingredients. This method results in a change in concentration with respect to the liquid.

**[0007]** Yet another method to cool a homogenized fluid product is to pass the fluid product through a heat exchanger to remove the heat from the fluid product. Although this method can reduce the temperature of the fluid product, it often takes a significant amount of time to cool the product to the desired fluid product temperature causing a loss in fluid product.

Brief Description Of The Drawings

**[0008]** It will be appreciated that the illustrated boundaries of elements (e.g., boxes or groups of boxes) in the figures represent one example of the boundaries. One of ordinary skill in the art will appreciate that one element may be designed as multiple elements or that multiple elements may be designed as one element. An element shown as an internal component of another element may be implemented as an external component and vice versa.

**[0009]** Further, in the accompanying drawings and description that follow, like parts are indicated throughout the drawings and description with the same reference numerals, respectively. The figures are not drawn to scale and the proportions of certain parts have been exaggerated for convenience of illustration.

**[0010]** **Figure 1** is a schematic diagram of one embodiment of a system **100** for heat treating a homogenized fluid product;

**[0011]** **Figure 2** illustrates one embodiment of a high shear mixing device **200** that can be used in the system **100** of **Figure 1**;

**[0012]** **Figure 3** illustrates one embodiment of a high shear mixing device **300** that can be used in the system **100** of **Figure 1**;

**[0013]** **Figure 4** illustrates one embodiment of a high shear mixing device **400** that can be used in the system **100** of **Figure 1**;

[0014] **Figure 5** illustrates one embodiment of a high shear mixing device **500** that can be used in the system **100** of **Figure 1**;

[0015] **Figure 6** is a schematic diagram of another embodiment of a system **600** for heat treating a homogenized fluid product;

[0016] **Figure 7** illustrates one embodiment of a methodology for heat treating a homogenized fluid product; and

[0017] **Figure 8** illustrates another embodiment of a methodology for heat treating a homogenized fluid product.

## Detailed Description Of Illustrated Embodiments

[0018] Illustrated in **Figure 1** is one embodiment of a system **100** for heat treating a homogenized fluid product. The system **100** can be practiced to heat treat many different types of fluid products such as pure liquid products, emulsions, liquid products carrying particles (e.g., suspensions), or liquid-gas dispersions. Fluid products may be produced for diverse uses such as food, beverages, pharmaceuticals, paints, inks, toners, fuels, magnetic media, and cosmetics. In one embodiment, the fluid product can be used in the food, pharmaceutical, and biotechnology industries and includes temperature sensitive material(s) that can be damaged and/or destroyed due to prolonged heating.

[0019] As shown in **Figure 1**, the system **100** generally includes a feed tank **115** for storing pre-mixed fluid product ingredients, a high shear mixing device **125** fluidly coupled to the feed tank **115** and being configured to process the pre-mixed fluid product ingredients into a homogenized fluid product, and a valve mechanism **130** fluidly coupled to the high shear mixing device **125**. As explained in further detail below, the valve mechanism **130** can direct a portion of the homogenized fluid product exiting the high shear mixing device **125** along a primary flow path **140** and a remaining portion of the homogenized fluid product along a cooling flow path **145**. The portion of the homogenized fluid product following the primary flow path **140** can be directed to one or more final processing stages.

**[0020]** The cooling flow path **145** can include a cooling device **135** fluidly coupled between the valve mechanism **130** and the high shear mixing device **125**. The cooling device **135** can be configured to cool the homogenized fluid product before it is returned to the high shear mixing device **125**. For example, the remaining portion of the homogenized fluid product following the cooling flow path **145** can be directed back to the high shear mixing device **125** and used as a cooling fluid for heat treating the newly homogenized fluid product to prevent damage to any temperature sensitive material present in the fluid product due to prolonged heating. By returning a portion of the homogenized fluid product (at a lower temperature) to the high shear mixing device **125** for heat treating the homogenized fluid product, there is little or no change in the concentration of the heat treated fluid product. Also, there is no need for separation of the cooling fluid since the cooling fluid is the homogenized fluid product at a lower temperature.

**[0021]** With further reference to **Figure 1**, one embodiment of the system **100** can include one or more sources **105** of fluid product ingredients or components. The fluid product sources **105** can be any type of storage container or tank capable of storing the fluid product ingredients. For simplicity, only three sources **105** of product ingredients are illustrated in **Figure 1** by way of example, but it will be appreciated that more or less fluid product ingredients could be used depending on the fluid product to be made. Fluid product ingredients can include, for example, liquids, solids, additives, gases, etc.

**[0022]** With further reference to **Figure 1**, the fluid product ingredients can be supplied from the sources **105** into a pre-mixing device **110**. The pre-mixing device **110** can be any suitable mixing device (e.g., propeller mixer, colloid mill, etc.) depending on the fluid product ingredients being mixed. After pre-mixing, the fluid product ingredients can then be fed into a feed tank **115**. Optionally, the pre-mixing of the fluid product ingredients may be performed inside the feed tank **115**.

**[0023]** The pre-mixed fluid product ingredients in the feed tank **115** can be supplied in the form of a stream to the high shear mixing device **125** via a pump **120**. The pump **120** may be any type of pump normally used for the fluid product, provided it can generate the required feed pressure for proper operation of the high shear mixing device **125**. In high pressure applications, a positive displacement pump such as a triplex or intensifier pump can be used.

[0024] As discussed above, the high shear mixing device **125** can be configured to process the pre-mixed ingredients to form a homogenized fluid product. Examples of suitable high shear mixing devices include, but are not limited to, homogenizers, hydrodynamic cavitation mixing devices, other static mixers and flow reactors, and jet meels. **Figures 2-5** illustrate several exemplary high shear mixing devices, which will be discussed in further detail below.

[0025] In one embodiment, the high shear mixing device **125** can be configured to include a local constriction of flow (not shown) where fluid product ingredients are forced under pressure through such local constriction of flow to effectuate high shear mixing of the fluid product ingredients in a high shear mixing zone (not shown) downstream from the local constriction of flow and thereby form a homogenized fluid product. Depending on the conditions (e.g., pressure and flow rate of the fluid stream and size and shape of the local constriction of flow), the fluid product ingredients may be subjected to not only high shear forces, but also impact forces and cavitation in the high shear mixing zone. The high shear mixing device **125** can also include a port (not shown) or other type of opening to permit introduction of a second fluid stream into the high shear mixing zone to effectuate mixing of the homogenized fluid product with the second fluid stream.

[0026] In another embodiment, the high shear mixing device **125** can be configured to permit introduction of at least two fluid streams (each including at least one fluid product ingredient) into a passageway (not shown) for impingement mixing of the fluid streams in a high shear mixing zone (not shown) and thereby form a homogenized fluid product. Depending on the conditions (e.g., pressure and flow rate of the fluid streams and the interaction between the fluid streams), the fluid product ingredients may be subjected to not only high shear forces, but also impact forces and cavitation in the high shear mixing zone. The high shear mixing device **125** can also include a port (not shown) or other type of opening to permit introduction of a third fluid stream into the high shear mixing zone to effectuate mixing of the homogenized fluid product with the third fluid stream.

[0027] Due to the shear forces, impact forces, and/or cavitation generated in the high shear mixing zone, the fluid product typically exits the high shear mixing device **125** at a temperature T2, which is greater than the input temperature of the fluid stream T1. For example, the

temperature of water can increase about 30°C after being passed through a local constriction of flow having a pressure drop of 20,000 psi (i.e., increase about 1°C - 2°C for every 1000 psi of pressure drop through the local constriction of flow). It will be appreciated that temperature increase may vary depending on the viscosity and density of the particular fluid, the concentration of the ingredients, and the geometry of the local constriction of flow. This increase in temperature can cause problems when the fluid product includes a temperature sensitive material that is used in the food, pharmaceutical, and biotechnology industries. For example, certain temperature sensitive materials can be damaged and/or destroyed if they reach a certain critical temperature.

**[0028]** To prevent damage and/or destruction of the temperature sensitive material present in the homogenized fluid product, the homogenized fluid product at temperature T2 can be cooled to a desired fluid product temperature, which is typically less than the critical temperature of the temperature sensitive material present in the homogenized fluid product. As explained in further detail below, the homogenized fluid product at temperature T2 can be cooled by mixing it with substantially the same homogenized fluid product at a temperature that is less than T2.

**[0029]** With further reference back to **Figure 1**, the fluid product typically exits the high shear mixing device **125** and enters the valve mechanism **130**. The valve mechanism **130** can direct a portion of the homogenized fluid product exiting the high shear mixing device **125** along a primary flow path **140** and a remaining portion of the homogenized fluid product at temperature T2 along a cooling flow path **145**. The valve mechanism **130** can be a manually-operated valve mechanism or a computer-controlled valve mechanism. Suitable valve mechanisms can include a two-way valve, a manifold system, or other fluid distribution system. In one embodiment, the selective portion of the fluid product directed along the cooling flow path **145** can be predetermined based on the viscosities and densities of the fluid product ingredients and the temperature, flow rate, and pressures of the fluid stream.

**[0030]** Along the primary flow path **140**, the homogenized fluid product can be directed to one or more final processing stages. For example, the primary flow path **140** can be in fluid communication with a container filling device **150**, such as an apparatus capable of filling bottles or cans with the fluid product. The container filling device **150** may optionally include a bowl

shaped reservoir for temporarily storing the liquid product. Alternatively, the homogenized fluid product flowing through the primary flow path **140** could be processed further and/or stored in a large container or tank (not shown).

**[0031]** Along the cooling flow path **145**, the homogenized fluid product can pass through the cooling device **135**. The cooling device **135** can be configured to cool the fluid product to a temperature T3, which can be less than temperature T2. For example, the difference in temperature between temperature T3 and temperature T2 can be at least about 10 °C. However, it will be appreciated that the difference in temperature between temperature T3 and temperature T2 can be at least about 1 °C depending on the homogenized fluid product being processed and the ingredients included therein. Alternatively, the difference in temperature between temperature T3 and temperature T2 can be at least about 1%. Examples of suitable cooling devices that can be used include, but are not limited to, a refrigerant-based cooling device, a shell and tube heat exchanger, or any other known heat exchange design.

**[0032]** The homogenized fluid product at temperature T3 can then be returned back to the high shear mixing device **125** via pump **155,** which can be similar to the pump **120** discussed above, and introduced into the high shear mixing zone for intimate mixing with the newly homogenized fluid product at temperature T2. The mixing of the cooled homogenized fluid product at temperature T3 with the newly homogenized fluid product at temperature T2 can heat treat the homogenized fluid product to the desired fluid product temperature. Additionally, because the cooled homogenized fluid product at T3 is introduced into the high shear mixing zone for mixing with the newly homogenized fluid product at temperature T2, the mixing conditions can be improved resulting in rapid heat treatment of the homogenized fluid product to the desired fluid product temperature. For example, the homogenized fluid product at temperature T2 can be cooled virtually instantaneously (e.g., within as little as a few microseconds) to minimize and/or prevent damage the temperature sensitive material present in the fluid product.

**[0033]** Once the system **100** is in operation and the valve mechanism **130** is directing appropriate portions of the homogenized fluid product along both the primary and cooling flow paths **140, 145,** the homogenized fluid product can exit the high shear mixing device **125** at the

desired fluid product temperature. However, it will be appreciated that to maintain the temperature of the homogenized fluid product exiting the high shear mixing device **125** at the desired fluid product temperature, an adequate amount of the homogenized fluid product exiting the high shear mixing device **125** at the desired fluid product temperature should still be directed along the cooling flow path **145**. This should ensure that an adequate supply of the cooled homogenized fluid product will be directed back to the high shear mixing device for mixing with the newly homogenized fluid product.

**[0034]** Optionally, to optimize the process, the system **100** may include temperature sensors provided: 1) at the inlet of the high shear mixing device **125** to detect the temperature T1 of the pre-mixed fluid product ingredients before they enter the high shear mixing device **125**; 2) directly after the local constriction of flow or in the high shear mixing zone to detect the temperature T2 of the homogenized fluid product before it mixes with the cooled homogenized fluid product; 3) at the outlet of the cooling device **135** to detect the temperature T3 of the cooled homogenized fluid product; and 4) at the outlet of the high shear mixing device **125** to detect the temperature T4 of the homogenized fluid product exiting the high shear mixing device **125**. Also, the system can optionally include flow meters provided at the inlet of the high shear mixing device **125** to detect the flow rate of the stream of pre-mixed ingredients before they enter the high shear mixing device **125** and at the outlet of the cooling device **135** to detect the flow rate of the cooled homogenized fluid product.

**[0035]** Optionally, the system **100** can further include a controller (not shown) including one or more microprocessors that can be used to regulate the temperature of the fluid product cooled in the cooling device **135**. The controller can also be used control other components in the system **100**, such as the pumps to regulate the pressure and flow rate of the fluid streams.

**[0036]** **Figure 2** illustrates a cross-sectional view of one embodiment of a high shear mixing device **200** that can be used in the system **100**. The device **200** is essentially a fixed-gap type homogenizer shown and described in U.S. Patent No. 4,944,602, which is hereby incorporated by reference in its entirety herein. The device **200** includes a flow-through channel or chamber **215**. The flow-through channel **215** can further include an inlet **220** configured to introduce a fluid stream into the device **200** along a path represented by arrow **A** and an outlet **225**.

[0037] The device **200** can further include a plate **230** provided in a chamber **235** downstream from the outlet **225** of the flow-through channel **215** thereby producing a gap therebetween (i.e., a local constriction **240** of flow). The local constriction **240** of flow can be configured to generate a high shear mixing zone **245** downstream from the local constriction **240** of flow and thereby form a resultant fluid product that exits the device **200** along a path represented by arrow **B**.

[0038] With further reference to **Figure 2**, the flow-through channel **215** can further include a port **250** for introducing a second fluid stream into the flow-through channel **215** along a path represented by arrow **C**. In one embodiment, the port **250** can be disposed in the chamber **235** downstream from the local constriction **240** of flow to permit the introduction of the second fluid stream into the high shear mixing zone **245**. It will be appreciated that any number of ports can be provided in the chamber **235** to introduce multiple fluid streams into the high shear mixing zone **245**.

[0039] **Figure 3** illustrates a cross-sectional view of one embodiment of a high shear mixing device **300** that can be used in the system **100**. The device **300** is essentially a orifice-type hydrodynamic caviatation device shown and described in U.S. Patent No. 5,969,207, which is hereby incorporated by reference in its entirety herein. The device **300** includes a wall **305** having an inner surface **310** that defines a flow-through channel or chamber **315**. The flow-through channel **315** can further include an inlet **320** configured to introduce a fluid stream into the device **300** along a path represented by arrow **A** and an outlet **325** configured to exit the resultant fluid product from the device **300** along a path represented by arrow **B**.

[0040] The device **300** can further include a cavitation generator that generates high shear forces and/or hydrodynamic cavitation downstream from the cavitation generator. For example, the device **300** can include a cavitation generator that can include a plate **330** having an orifice **335** disposed therein to produce a local constriction of flow. It will be appreciated that the plate can be embodied as a disk when the flow-through channel **315** has a circular cross-section, or each plate can be embodied in a variety of shapes and configurations that can match the cross-section of the flow-through channel **315**. To vary the degree and character of the cavitation field generated downstream from the plate **330**, the orifice **335** can be embodied in a variety of

different shapes and configurations. It will be appreciated that the orifice **335** can be configured in the shape of a Venturi tube, nozzle, orifice of any desired shape, or slot. Further, it will be appreciated that the orifice **335** can be embodied in other shapes and configurations such as the ones disclosed in U.S. Patent No. 5,969,207. In this embodiment, the orifice **335** disposed in the plate **330** can be configured to generate a high shear forces and/or hydrodynamic cavitation in a zone **340** downstream from the orifice **335**.

**[0041]** With further reference to **Figure 3**, the flow-through channel **315** can further include a port **345** for introducing a second fluid stream into the flow-through channel **315** along a path represented by arrow **C**. In one embodiment, the port **345** can be disposed in the wall **305** downstream from the local constriction **340** of flow to permit the introduction of the second fluid stream into the mixing zone **340**. It will be appreciated that any number of ports can be provided in the wall **305** to introduce multiple fluid streams into the mixing zone **340**.

**[0042]** **Figure 4** illustrates a cross-sectional view of one embodiment of a high shear mixing device **400** that can be used in the system **100**. The device **400** is essentially a baffle-type hydrodynamic caviatation device shown and described in U.S. Patent No. 5,969,207. The high shear mixing device **400** includes a wall **405** having an inner surface **410** that defines a flow-through channel or chamber **415**. The flow-through channel **415** can further include an inlet **420** configured to introduce a fluid stream into the device **400** along a path represented by arrow **A** and an outlet **425** configured to exit the resultant fluid product from the device **400** along a path represented by arrow **B**.

**[0043]** The device **400** can further include a cavitation generator that generates high shear forces and/or hydrodynamic cavitation downstream from the cavitation generator. For example, the device **400** can include a cavitation generator, such as a disc-shaped baffle **430**. To vary the degree and character of the cavitation fields generated downstream from the baffle **430**, the baffle **430** can be embodied in a variety of different shapes and configurations. It will be appreciated that the baffle **430** can be embodied in other shapes and configurations such as the ones disclosed in U.S. Patent No. 5,969,207. In this embodiment, the baffle **430** can be configured to generate a high shear forces and/or hydrodynamic cavitation in a mixing zone **435** downstream from the baffle **430** via a local constriction **440** of fluid flow. For example, the local

constriction **440** of liquid flow can be an area defined between the inner surface **410** of the wall **405** and an outer surface of the baffle **430**.

**[0044]** With further reference to **Figure 4**, the flow-through channel **415** can further include a port **445** for introducing a second fluid stream into the flow-through channel **415** along a path represented by arrow **C**. In one embodiment, the port **445** can be disposed in the wall **405** downstream from the local constriction **440** of flow to permit the introduction of the second fluid stream into the mixing zone **435**. It will be appreciated that any number of ports can be provided in the wall **405** to introduce multiple fluid streams into the mixing zone **435**.

**[0045]** **Figure 5** illustrates a cross-sectional view of one embodiment of a high shear mixing device **500** that can be used in the system **100**. The device **500** is essentially a classic fluid impingement device shown and described in U.S. Patent No. 2,751,335, which is hereby incorporated by reference in its entirety herein.

**[0046]** The device **500** includes a housing **505** defining a passageway **510** configured to permit introduction of at least two fluid streams, represented by arrows **A**, therein through openings **512** for impingement mixing thereof. The impingement of the two fluid streams can generate high shear forces, impact forces, and/or hydrodynamic cavitation in a mixing zone **515** in the passageway **510**. The device **500** can further include an outlet **520** configured to exit the resultant fluid product from the device **500** along a path represented by arrow **B**.

**[0047]** In one embodiment, the housing **505** can further include a port **525** for introducing a third fluid stream into the passageway **510** along a path represented by arrow **C**. In one embodiment, the port **525** can be disposed in the housing **505** to permit the introduction of the second fluid stream into the mixing zone **515**. It will be appreciated that any number of ports can be provided in the wall **505** to introduce multiple fluid streams into the mixing zone **515**.

**[0048]** Illustrated in **Figure 6** is another embodiment of a system **600** for heat treating a homogenized fluid product. The system **600** can include similar components and operate in a similar manner to the system **100**, except that the system **600** lacks the cooling flow path **145** of the system **100**. Instead, the system **600** can include a separate source **605** of the homogenized

fluid product that is stored at temperature T3. The homogenized fluid product at temperature T3 is substantially the same fluid product as the fluid product at temperature T2 (i.e., having substantially the same components and concentration levels).

**[0049]** Like the system **100** discussed above, the system **600** can be configured to permit the homogenized fluid product at temperature T3 to be supplied to the high shear mixing device **125** via pump **155** and introduced into the high shear mixing zone for intimate mixing with the newly homogenized fluid product fluid product at temperature T2. The mixing of the cooled homogenized fluid product at temperature T3 with the newly homogenized fluid product at temperature T2 can heat treat the homogenized fluid product to the desired fluid product temperature. Additionally, because the cooled homogenized fluid product at T3 is introduced into the high shear mixing zone for mixing with the newly homogenized fluid product at temperature T2, the mixing conditions can be improved resulting in rapid heat treatment of the homogenized fluid product to the desired fluid product temperature.

**[0050]** Illustrated in **Figure 7** is one embodiment of a methodology associated with heat treating a fluid product. The illustrated elements denote "processing blocks" and represent functions and/or actions taken for heat treating a fluid product. In one embodiment, the processing blocks may represent computer software instructions or groups of instructions that cause a computer or processor to perform an action(s) and/or to make decisions that control another device or machine to perform the processing. It will be appreciated that the methodology may involve dynamic and flexible processes such that the illustrated blocks can be performed in other sequences different than the one shown and/or blocks may be combined or, separated into multiple components. The foregoing applies to all methodologies described herein.

**[0051]** With reference to **Figure 7**, the process **700** includes feeding fluid product ingredients under pressure through a local constriction of flow to effectuate high shear mixing of the fluid product ingredients and thereby form a fluid product at a first temperature (block **710**). The high shear mixing of the fluid product ingredients can take place in, for example, a high shear mixing zone downstream from the local constriction of flow. A sufficient amount of the fluid product at a second temperature can then be mixed with the fluid product at the first

temperature to thereby heat treat the fluid product (block **720**). In one embodiment, the second temperature can be less than the first temperature resulting in the cooling of the fluid product when the fluid product at a second temperature is mixed with the fluid product at the first temperature.

**[0052]** Illustrated in **Figure 8** is another embodiment of a methodology associated with heat treating a fluid product. With reference to **Figure 8**, the process **800** includes introducing at least two streams of fluid components into a passageway for impingement mixing thereof to thereby form a fluid product at a first temperature (block **810**). A sufficient amount of the fluid product at a second temperature can then be introduced the passageway to effectuate mixing of the fluid product at the first temperature with the fluid product at the second temperature to thereby heat treat the fluid product (block **820**). In one embodiment, the second temperature can be less than the first temperature resulting in the cooling of the fluid product when the fluid product at a second temperature is mixed with the fluid product at the first temperature.

**[0001]** The present invention is further described by the following non-limiting example. The example is merely illustrative and does not in any way limit the scope of the present invention as described and claimed.

<u>Example 1</u>

**[0053]** Utilizing the system **600** illustrated in **Figure 6** and a circular orifice-type high shear mixing device **300** substantially similar to the one illustrated in **Figure 3** and described above, four experiments were conducted with water as the fluid stream at various flow rates. For all four experiments, the pressure differential in the orifice of the high shear mixing device was 15,000 psi and the input temperature (T1) of the water stream (Stream A) into the high shear mixing device was 20.7 °C.

**[0054]** The results of the experiments are illustrated in Chart I below. Mixing Zone represents the homogenized fluid product downstream from the orifice (i.e., in the high shear mixing zone) before such homogenized fluid product is mixed with Stream C. The temperature of the homogenized fluid product in the Mixing Zone is indicated as T2. Stream C represents a water stream from a separate, cold water source. The temperature of Stream C is indicated as

T3. Stream B represents the mixed water streams exiting the high shear mixing device **300** (i.e., Stream A and Stream C). The temperature of Stream B is indicated as T4.

Chart I

| Mixing Zone | | Stream C | | Stream B | |
|---|---|---|---|---|---|
| Flow Rate (GPM) | T2 (°C) | Flow Rate (GPM) | T3 (°C) | Flow Rate (GPM) | T4 (°C) |
| 1.2 | 46.9 | 1.8 | 12.9 | 3.0 | 25.3 |
| 1.2 | 45.8 | 1.2 | 13.5 | 2.4 | 27.5 |
| 1.2 | 46.6 | 0.9 | 13.7 | 2.1 | 29.9 |
| 1.2 | 46.7 | 0.6 | 13.5 | 1.8 | 32.2 |

**[0055]** While the present invention has been illustrated by the description of embodiments thereof, and while the embodiments have been described in considerable detail, it is not the intention of the applicants to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention, in its broader aspects, is not limited to the specific details, the representative apparatus, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of the applicant's general inventive concept.